MONTANA DEPARTMENT OF TRANSPORTATION

ROAD DESIGN MANUAL

Chapter 10

Work Zone Traffic Control

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Contents

Chapter 10

Work Zone Traffic Control

Traveling through a construction zone can be difficult and confusing to drivers. A well-planned traffic control design can alleviate many of these difficulties and confusions. This chapter provides information for developing a safe and well-conceived transportation management plan (TMP), including construction options, geometric design of crossovers and detours, and roadside safety through construction zones.

10.1 DESIGN PRINCIPLES AND APPROACH

The primary function for temporary traffic control is to provide for the safe and efficient movement of roadway users through or around work areas while protecting construction personnel and equipment, and allowing for efficient construction and maintenance of the facility. Key principles are, but not limited to, the following:

- Develop clear signage and pavement markings well in advance and through the construction area;
- Avoid frequent and/or abrupt changes in roadway geometry and/or speed;
- Use traffic control devices that highlight and emphasize the appropriate path; and
- Minimize the inconvenience to traffic during construction.

The TMP must provide an appropriate design that meets traveler expectation, but additional risk may be assumed due to the temporary nature of this type of design. The design team should work closely with the Traffic and Safety Bureau and construction personnel to communicate the intent and limitations of temporary design features and ensure that this is then communicated to the public that these areas can be navigated with additional caution.

The *MDT Work Zone Safety and Mobility (WZSM) Guidance* provides the goals and objectives, guidelines, procedures, and processes related to work zone safety and mobility for MDT employees, construction workers, and the public (*1*). The vision for the WZSM Guidance is to plan, design, construct, and maintain highway construction zones that optimize work zone safety and roadway user mobility while minimizing stakeholder and environmental impacts.

The WZSM Guidance includes five goals, each with their respective objectives and performance indicators. The goals are:

1. Reduce the number and severity of crashes, injuries and fatalities in construction zones;
2. Monitor and continually improve current management practices of construction and maintenance operation roadway user impacts;
3. Ensure appropriate level of knowledge, skills, and abilities for responsible parties to manage and evaluate construction zone safety and mobility;
4. Minimize stakeholder impacts; and
5. Optimize construction zone traffic control design and implementation.

All construction and maintenance work on MDT facilities requires a TMP, and the amount of detail that is included in the TMP depends on the anticipated level of impact of the construction zone. The plans will include up to three components, depending on the level of impact: a traffic control plan (TCP), transportation operations (TO), and public information (PI). The TCP describes measures within the contract to facilitate roadway users through a construction zone, work zone, or an incident area, and it addresses traffic safety and control through the construction and work zone. The TO plan includes the identification of strategies used to mitigate impacts of the construction zone on the operation and management of the transportation system within the construction zone impact area. The PI component of the TMP includes communication strategies that seek to inform affected roadway users, the general public, area residences and businesses, and appropriate public entities about the project, the expected construction zone impacts, and the changing conditions of the project. This chapter primarily covers the TCP, as it is the most directly relevant to roadway design.

There are three levels of impact of the construction zone:

- Level 1: Significant regional impact for highway users and businesses.
- Level 2: Moderate, localized impact to highway users, businesses, and adjacent properties.
- Level 3: Little to no impact.

More information can be found in the WZSM Toolbox.

Work Zone Safety and Mobility Toolbox

10.2 TRAFFIC MANAGEMENT

Highway construction will disrupt normal traffic operations; therefore, MDT requires every project to address traffic control through construction zones. This may range in scope from very detailed plans to merely referencing the *MDT Detailed Drawings* and the *Manual on Uniform Traffic Control Devices (MUTCD) (2)*.

With much of MDT's highway program involved in upgrading existing highways, a comprehensive traffic control plan is essential. This will minimize the operational and safety challenges through the construction zones.

10.2.1 Responsibilities

MDT requires a coordinated effort from various units to implement a successful TCP through construction zones. The following discusses the responsibilities of these MDT units:

- **Preconstruction**. Preconstruction will consist of the design team working in collaboration with District traffic and construction staff. The responsibilities of the Preconstruction staff include, but are not limited to, the following:
    a. Determining the sequence of operations, the need for detours, crossovers, and lane closures that will be used in the project;
    b. Providing at least one acceptable construction method that can be used on the project;
    c. Developing the geometric design for specially constructed detours, lane closures and crossovers;
    d. Developing draft special provisions for traffic control and sequence of operations;
    e. Ensuring that a detailed review is given to the proposed TCP during the project design plan reviews;
    f. Providing quantities for temporary pavement markings, detours, crossovers, temporary guardrail, and other traffic control items to be paid for with specific bid items; and
    g. Revising Traffic Control estimates as appropriate.
- **Construction Oversight.** Construction Oversight will consist of the District traffic/construction staff working in collaboration with the design team. The responsibilities of the Construction Oversight staff include, but are not limited to, the following:
    a. Developing the detailed TCP for the project;
    b. Ensuring that the proper selection and placement of traffic control devices occurs (e.g., pavement markings, barricades, signing);
    c. Addressing the roadside safety concerns through the construction zones (e.g., construction clear zones, temporary barriers, placement of construction equipment and supplies);
    d. Making provisions for informing the public through various media options of the necessary project information (e.g., proposed road closure); and
    e. Providing quantities for traffic control devices.

10.2.2 Evaluations

The objective of the TCP is to provide a strategy that will efficiently and safely move traffic through or around the construction zone. The design team should coordinate with the Construction Section when preparing a TCP. For projects impacting the operations of the system beyond the project or for modified use of existing facilities, the design team should coordinate with the Traffic and Safety Bureau when preparing a TCP. To accomplish this strategy, evaluate the following when preparing a TCP:

- **Preliminary Review**. Conduct a preliminary discussion of the TCP during the Preliminary Field Review. The discussion should include, but is not limited to, items such as methods of traffic control that will be feasible for the project, location of detours, and duration of various construction aspects.
- **Engineering.** Some of the engineering aspects to consider include:
    a. **Highway Capacity**. The TCP should provide adequate capacity to handle the expected traffic volumes through the construction zone or detour at an acceptable level of service. This may require converting shoulders to travel lanes, eliminating on-street parking, constructing temporary lanes, opening additional lanes during peak periods, or providing public transportation.
    b. **Geometrics**. The TCP should have suitable geometry so that a driver can safely maneuver through the construction zone, day or night. Frequent and abrupt changes in geometrics, such as crown changes, lane narrowing, lane drops or mainline transitions that require rapid maneuvers, should be avoided. Section 10.4 presents geometric design criteria for construction zones.
    c. **Roadside Safety**. Providing a safe environment both for the traveling public and construction workers is an essential element through construction zones. Traffic safety through construction zones should be an integral and high priority of every project from planning through design and construction. Section 10.5 addresses roadside safety challenges through construction zones.
    d. **Overhead Lighting**. If the existing roadway has overhead lighting, it must be maintained during construction.
- **Constructability.** The design team should evaluate the proposed construction sequence to determine if the project can be constructed based on the proposed TCP. Some of the elements the design team should evaluate include:
    a. Whether traffic will be able to safely maneuver through all the proposed intermediate horizontal and vertical alignment steps;
    b. The location of adjacent traffic relative to worker and traffic safety;

c. Whether there is sufficient room for equipment maneuverability, as well as access locations for construction traffic; and

d. Whether the construction phasing is appropriate.

- **Construction.** There are several construction options available that will improve the TCP. These should be discussed during the design phase of the project. Some of these options include:

  a. The use of special materials (e.g., quick curing concretes that will allow traffic within hours of pouring);

  b. The use of special designs (e.g., using precast box culverts versus cast-in-place box culverts or bridges);

  c. Requiring special scheduling requirements which will reduce traffic disruptions (e.g., working at night, lane closure during off-peak periods);

  d. Developing project phasing plans which will allow traffic to use the facility prior to project completion; and

  e. Contractor alternate bidding methods such as A+B bidding or cost incentives/disincentives for early/late completion of construction may be useful for projects having significant traffic control issues. Where there is Federal Highway Administration (FHWA) oversight, these methods must be justified and approved by FHWA.

A+B Bidding: This cost-plus-time method of bidding enables the contractor to determine a reasonable contract duration required for project completion; thus allowing the contractor to control the important element of time.

- **Operation Selection.** The initial determination on whether the project will require detours, lane closures, crossovers, and temporary closures should be made during the Preliminary Field Review (PFR). Section 10.3 provides additional guidance for determining which of these various construction applications may be appropriate.
- **Business.** In urban areas, an in-depth public involvement plan is necessary to coordinate the TCP with local businesses. If at all possible, access to at least one of any business's approaches must be maintained during business hours.
- **Maintenance.** Include provisions describing how the road will be maintained and who will be responsible for snow removal during winter conditions.
- **Pedestrians and Bicycles.** Safe accommodation of pedestrians and bicyclists through the construction zone should be addressed early in project development. Situations that would normally warrant special pedestrian and bicyclist considerations may include locations where sidewalks traverse the construction zone, where a designated school route traverses the construction zone, where significant pedestrian and bicyclist activity or evidence of such activity exists and where existing land use generates pedestrian and bicyclist activity (e.g., parks, schools, shops).

Consider the following principles when addressing pedestrian and bicycle accommodation through construction zones:

a. Physically separate pedestrians and vehicles from each other.

b. Ensure pedestrian walkways and bicycle paths are free of any obstructions and hazards (e.g., holes, debris, mud, construction equipment, stored materials).

c. Consider temporary lighting for all walkways that may be used at night, particularly if adjacent walkways are lit.

d. Clearly delineate all hazards (e.g., ditches, trenches, excavations) near or adjacent to walkways.

e. Evaluate whether walkways under or adjacent to elevated work activities (e.g., bridges, retaining walls) need to be covered.

f. Where pedestrian walkways and bicycle paths cannot be provided, then direct pedestrians and bicyclists to an alternative safe location (e.g., the other side of the street).

g. Stage construction operations so that, if there are two walkways, they are not out of service at the same time.

h. Plan the construction so that any temporary removal of sidewalks in front of land uses such as businesses and schools can occur in the shortest amount of time practical or be scheduled around non-peak pedestrian times (e.g., summer construction around schools).

i. Ensure that all temporary sidewalks meet the handicapped accessibility requirements for surface, curb ramps, sidewalk cross slopes, longitudinal slopes, etc. For more information on handicapped accessibility criteria, see Chapter 1, Section 1.5.1, Chapter 7, Section 7.3.2, and the *MDT Baseline Criteria Practitioner's Guide* (*3*).

Refer to the MUTCD for additional guidance regarding pedestrian and bicycle facilities in construction zones.

- **Heavy Vehicles.** Oversized vehicles are often detoured around construction sites or staged for passage through the construction zone during designated periods. The design team should consider the horizontal clearance if temporary concrete barrier rail (TCBR) is installed along both sides of the temporary roadway to accommodate oversize/overweight heavy vehicles. The design team should provide 14 feet of width, if possible. Evaluate the need for and placement of wide load detours, signing and other considerations during the Preconstruction TMP process. Consider coordination with Motor Carrier Services for potential wide load restrictions and/or posting width restrictions on the MCS website.

10.2.3 Documentation

The design team should document the proposed traffic control methods and features in each milestone report as described in the report templates and on the TMP worksheet, if applicable.

In addition to general information, provide specific design information when traffic control for a project will require variations from design guidance provided in this chapter, when using existing routes or modifying full buildout features for detouring traffic, and when unique or complex traffic control features are used. More information on these reports can be found in Chapter 1, Section 1.3.4, and at the following link on the MDT Website.

Project Reports

10.3 CONSTRUCTION APPLICATIONS

The following sections present several construction applications that the design team should consider when developing the project phasing. The variables that affect the needs of the construction zone include location of work, roadway type, speed, traffic volume, geometrics, vertical and horizontal alignment, pedestrians, bicycles, oversize/overweight trucks, and intersections. The design team should understand that each construction zone is different and that not all applications will apply on every project. For most projects, there may be more than one alternative. Typical applications should be altered to fit the conditions of the particular construction zone. All temporary traffic control features must be in accordance with the *MUTCD (2)*.

10.3.1 Work Outside of the Roadway

Traffic will generally not be impeded when the construction area is outside of the roadway. The design team should ensure that there are enough access points available to the contractor to allow for construction equipment to exit, enter, or cross the highway in a safe manner. Sufficient sight distance should be available to both the motorist and the equipment operator.

10.3.2 Shoulder Work and Partial Lane Closures

Shoulder work which does not encroach into the travel lane will generally have minimal impact on traffic if proper signing is provided to advise the motorist. Workers may require protection with the appropriate channelizing devices, temporary barrier and/or a truck-mounted attenuator. Work spaces should be closed off by a taper or channelizing device with the appropriate length as provided in Section 10.4.3.

Partial lane closures may be appropriate where there are:

- Short construction durations;
- Minimal hazardous conditions (e.g., no drop-offs greater than 6 inches next to the roadway); and
- Minimal impacts to traffic.

Where partial lane closures are used, the remaining lane width should be 11 feet. However, a 10-foot lane width may be used on low-volume roadways that have low truck volumes. Use full-lane closures rather than partial lane closures where there is a substantial volume of wider vehicles (e.g., trucks, buses, recreational vehicles) or where construction is adjacent to high-speed traffic. The following sections provide information for full lane closures.

10.3.3 Lane Closure (Two-Lane Highways)

Lane closures on two-lane highways will generally require shifting traffic to the shoulder or providing traffic for both directions on a one-lane roadway through the use of flaggers and pilot cars. The design team should consider alternative treatments (e.g., detours based on duration and length of the lane closure and the traffic volume).

Where detours are impractical, consider reconstructing existing shoulders to allow them to be used as a temporary traffic lane. Proper signing and pavement markings with the appropriate geometry are necessary to shift traffic to the appropriate locations. See Section 10.3.7.

Based on the duration and length of the detour and on the traffic volume, the use of alternating traffic on one-lane roads may be acceptable. This strategy is commonly used with the reconstruction of low-volume bridges where each side is reconstructed in separate phases. Adequate sight distance and signing must be available at the site to ensure the motorist understands the appropriate action to take. For daily closures, flaggers may be used to control traffic through the site. For long-term closures, consider using temporary traffic signals to control traffic through the construction zone.

10.3.4 Single-Lane Closures (Four-Lane Highways)

Single-lane closures on divided facilities may be appropriate if:

- They will only cause minor delays during peak time periods, and
- The construction will not result in a substantial increase in hazards to traffic and/or construction personnel.

In urban or other high-volume areas, consider reconstructing and shifting traffic to the shoulder or reducing lane widths to maintain both lanes of traffic in each direction through the construction area. If narrower lanes are used, ensure wide loads can still be accommodated (e.g., alternative routes are available). All lane shifts should meet the taper lengths presented in Section 10.4.3.

10.3.5 Two-Way Traffic on Divided Highways

10.3.5.1 Guidelines

The decision on when to use two-way traffic on one of the two roadways of a divided highway will be made on a project-by-project basis. The input of Construction personnel is essential. In making this decision, consider the following factors:

- **Lane and Shoulder Widths.** The minimum allowable lane and shoulder widths are dependent on the volume of traffic and the percentage of trucks. Use Exhibit 10-1 to determine the shoulder width of the single roadway.

Exhibit 10-1
Shoulder Width Criteria

DHV for 12-Foot Lane Widths	Shoulder Width
1000	4 feet or greater
800	2 feet
700	0

- **Construction Efficiency**. Separating the traffic from the construction activity will result in increased construction efficiency. However, the increased efficiency may be minimal for activities that can be readily performed with staged construction (one lane at a time), such as cold milling or paving. Closure of a roadway on a divided highway provides the greatest advantage when the construction activity requires grading or an item that would result in temporary closure of one roadway, such as the replacement of a drainage structure.
- **Project Length**. Closing a single roadway may result in a significant reduction in the operational efficiency of the remaining roadway. The design team should consider the traffic volume, the length, and the roadway gradients of the two-way traffic because it may result in undesirable traffic congestion. The evaluation of these factors is covered in Section 10.2.2.
- **Width Restrictions.** A single roadway should not restrict the width of vehicles because of reduced lane or shoulder widths. Where it is necessary to restrict the roadway width, the design team should coordinate with the Motor Carrier Services.
- **Alternate Route Detours.** This option is generally only practical if both roadways of a divided highway are closed at the same time. However, the design team should only consider this alternative if no other option is practical. The alternate route should be a facility capable of effectively accommodating the traffic of the divided highway. The decision to use an alternate route requires completion of the full TMP process (project worksheet and review team) and must include the evaluation and documentation of the features discussed in Section 10.2.2. Special consideration is needed for alternate routes providing multiple lanes of travel in the same direction. The driver expectancy for detour routes such as these is much greater, and higher design speeds and associated design criteria are required. The design speed of all alternate routes should be included in the plans package on all applicable detail sheets and special provisions
- **Temporary Lanes in Flush Median**. Providing temporary lanes is usually only practical where the traffic volumes would exceed the

capacity of the single roadway. The length of temporary lanes should be kept to a minimum.

10.3.5.2 Design

The following provides several design considerations where two-way traffic on a single roadway of a divided highway is used:

- **Length.** The design team should consider the length of the two-way traffic because operational efficiency is often reduced for two-way traffic on divided highways, resulting in traffic congestion. Where the DHV is less than the values shown in Exhibit 10-1, the length of two-way traffic can be extended to the limits of the project. When the DHV is greater than these values, the design team should consider installing additional crossovers to alleviate congestion. Based on MDT practice; typically, two-way traffic should be as short as practical, and lengths in excess of 4 miles should be avoided. The type of work, number and location of work zones, the roadway gradients, and the number and location of interchanges within the project should be considered when determining the number and locations of crossovers. The need for additional crossovers should ultimately be determined by the review team.
- **Positive Protection**. Positive protection is typically only provided for work zones. The design team should coordinate with the Construction Bureau, as well as the Traffic and Safety Bureau to determine the appropriate treatment in this transition area. More considerations for positive protection can be found in Section 10.5.2.
- **Roadside Safety.** The design team should consider the effect that directing traffic onto the opposing roadway will have on the roadside appurtenances. For example, existing trailing ends of unprotected bridge ends may require approach guardrail transitions or impact attenuators, and all guardrail terminals may need to be converted to an acceptable treatment. Re-lapping the existing guardrail in the opposite direction, such that each piece of W-Beam encountered by the adjacent traffic overlaps each subsequent piece of rail at the splices, is generally not required for the temporary change in direction of travel.
- **Crossovers.** Consider the following in the design of crossovers:
    a. Tapers for lane drops should not be contiguous with the crossovers. See Section 10.4.3 for acceptable taper lengths and rates. A taper rate of 12:1 should be used for the crossover. The 12:1 taper rate is used because it is comparable to what is used for exit ramps. The crossover is similar because the driver is leaving the 4-lane facility and entering a two-lane facility. The same rate should be used for a ramp crossover.
    b. The crossover should have a design speed that is no more than 25 miles per hour below the mainline design speed before the construction zone; see Section 10.4.1. All design

Temporary barrier and the excessive use of traffic control devices cannot compensate for a poor geometric design of a crossover.

speed decisions should be properly documented in the appropriate plans and reports (see Section 10.2.3).

c. The design of the crossover should accommodate the truck traffic of the roadway (e.g., surfacing widths, loads).

d. A clear recovery area should be provided adjacent to the crossover; see Section 10.5.3.

e. See the *MDT Detailed Drawings* for the geometric details of a typical crossover.

- **Interchanges.** Access to interchange ramps on freeways should be maintained even if the work space is in the lane adjacent to the ramps. If access is not practical, ramps may be closed for the shortest duration possible using proper signing for alternative ramps and detours. Early coordination with local officials having jurisdiction over the affected cross streets will be required prior to ramp closures.

  Providing access to exit and entrance ramps may require the use of additional crossovers. Sufficient deceleration and acceleration distances should be provided.

10.3.6 Work Within or Near Intersections

If the work is within or near an intersection, consider the following guidelines:

- Keep the work space small so that traffic can move around it.
- For temporary work at unsignalized intersections, maintain intersection traffic control via flaggers, temporary signals or signs.
- Coordinate with construction during the TMP meeting if staging is appropriate to maintain traffic flow and manage the work zone area. Reduce traffic volumes by detouring traffic upstream from the intersection.

Where lane shifts are used through signalized intersections, the traffic signal heads and actuated detectors will need to be re-adjusted for the temporary lane configuration. Coordinate with the Traffic and Safety Bureau for information on traffic signal designs.

10.3.7 Detours

10.3.7.1 Warrants

Detours are necessary when traffic cannot be adequately or safely maintained through the construction project on the existing roadway. Detours provide the safest method of protecting workers within the construction zone. Detours allow the contractor to work unimpeded by traffic, which will typically accelerate the project completion time. On the other hand, detours may cause inconvenience and confusion to the traveling public.

The following presents guidelines for where detours should be considered:

- Where there is a possibility of a significant hazard to traffic and/or workers.

- Where removal of traffic will substantially accelerate the project completion time.
- Where construction would be impractical if traffic was maintained (e.g., total bridge reconstruction, substantially raising fill heights).
- Where work is done at railroad crossings. (For example, this work will generally require the closing of the roadway for one to two weeks, depending on the site).

10.3.7.2 Types

Once it has been determined that a detour is necessary, consider the following detour types:

- **Existing Routes.** Detours along existing routes are generally the easiest option available. The following factors should be considered:
    a. Considerable public involvement and coordination with the affected communities and local maintaining agencies will be necessary before traffic can be detoured onto an existing route.
    b. Detours will generally require more travel time.
    c. The proposed detour route should have sufficient capacity to safely accommodate the additional traffic.
    d. Detour traffic may increase traffic delays and congestion on local roads (e.g., side streets in towns).
    e. Existing traffic signals may need to be reprogrammed or temporary traffic signals installed.
    f. Improvements may be required on the detour route to accommodate the increased road traffic (e.g., pavement resurfacing, increasing bridge loading capacities, roadside safety improvements).
    g. Ensure that structures over the alternate route provide adequate clearance and have sufficient loading for detoured traffic.
    h. The increased number/density of approaches on the alternate route may decrease the operational efficiency (especially where traffic is being detoured from a controlled access facility).
    i. Local access and approaches may still be required within the construction area.
    j. Address adequacy of the clear zone for the increased volumes.
- **Temporary Roadways**. Temporary roadways (e.g. adding lanes in the median, widening of the subgrade) are generally provided within the construction area versus detouring traffic around the area. Temporary roadways are typically constructed where:
    a. A long detour would be required,
    b. Alternate routes are impractical,

c. A heavy volume of traffic would need to be detoured,
d. Substantial improvements would need to be made to the detour route,
e. Increased truck volumes through towns would be unacceptable,
f. The detour duration would be required for a long period of time, and/or
g. Lane restrictions to create adequate work zones are impractical due to traffic volumes.

Due to the limited space available, the geometric design of temporary roadways is often much more restricted. Sections 10.4 and 10.5 provide the geometric and roadside safety criteria that should be used for temporary roadways.

The installation of drainage structures associated with temporary roadways generally requires a staged construction sequence. The preferred sequence of culvert installation should proceed from downstream to upstream. Sufficient additional culvert lengths are necessary to provide adequate lane widths and fill slopes during the installation.

- **Constructed Detours.** Constructed detours are specially constructed temporary roadways that are built within the construction zone to bypass a bridge, railroad crossing or other similar "spot" construction area. These detours are constructed where it would be impractical to detour traffic on other existing routes. The majority of constructed detours are associated with the installation of bridges and other drainage facilities.

Design the detours using the criteria in Sections 10.4 and 10.5. However, it should be noted that they are generally more expensive, may require the purchase of construction permits, and may have adverse environmental impacts.

10.3.7.3 Location

Consider the following factors when determining detour locations:

- The detour should minimize impacts to adjacent development.
- The detour should minimize the amount and cost of utility relocations.
- The detour should minimize environmental impacts.
- Locate detours which cross watercourses downstream from the construction, where practical.
- Ensure the detour is offset a sufficient distance so as not to interfere with the construction. For bridge replacements or for existing bridges that need to be removed, attempt to provide at least 10 feet between the outside edge of the new structure or existing structure to be removed (usually the wingwalls) and the toe of the detour cut or fill slope.

Coordinate the location of detours around bridge construction sites with the Bridge Bureau.

- Evaluate the length of the detour to determine if it is cost effective to extend the detour beyond the construction zone (on short projects such as bridge replacements this decision may result in a detour that is longer than the project). It is sometimes practical that the additional cost to provide a longer detour is offset by reduced estimated traffic control costs and/or contract time.
- Coordinate the location of detours around bridge construction sites with the Bridge Bureau to ensure that adequate offset is provided.

10.3.8 Offset Alignment

For reconstructed projects, it may be cost effective to use a new alignment which is offset and generally parallel to the existing roadway. Some of the factors that should be evaluated to determine if an offset alignment may be appropriate include:

- Construction cost savings,
- Project constructability,
- Right-of-way availability and costs,
- Potential contract time reduction and road user costs,
- Existing development of adjacent property, and
- Natural features.

There are special challenges when an offset alignment is used, including the design of the connection to the existing roadway, obliteration of the existing roadway, and how to utilize material from the existing fills while maintaining traffic on the existing roadway. The effectiveness of an offset alignment may be reduced where a project involves substantial modifications to the vertical alignment. In these cases, the construction limits often encompass the present traveled way (PTW).

10.3.9 Urban Routes

Construction on urban routes presents its own unique set of challenges and considerations that should be discussed and coordinated as part of the TCP, TO and PI components of the TMP process. Major considerations include:

- **Pedestrian/bicycle access**. Refer to Chapter 7, Chapter 8 and the *MUTCD* for design considerations related to pedestrians and bicycles in urban environments.
- **Intensive public relations program.** Provisions need to be included in the contract to notify motorists, businesses, and residents of closures, delays and other factors that may affect them. These can include media notification and weekly meetings with city officials and local business people.
- **Utility considerations**. Replacement of storm drain, sanitary sewer and water lines often require the closure of a street to traffic. Sequencing must be addressed in detail and should be closely coordinated with District Construction.

- **Access for emergency vehicles**. Ensure that access is provided through provisions for roadway width and coordination with emergency response providers.
- **Impacts to businesses and residents.** Impacts must be minimized as much as practical. This typically requires extensive traffic control signing plans.

10.3.9.1 Detour Traffic onto an Existing Route

Detouring traffic onto other streets is fairly common for construction projects on urban routes. Closing a single block at a time in a block-by-block sequence helps to minimize disruption to local businesses and residents as well as traffic. Since sequencing is important in urban construction, the design team needs to coordinate with District Construction. In addition to the considerations listed previously in Section 10.2.2, the following items should be considered.

- **Traffic volumes.** The design team should consider if the adjacent streets can handle the additional traffic volumes. Temporary signing can be used to enhance traffic movements. Converting adjacent streets to one-way traffic should also be considered.
- **Pedestrian accommodation.** The alternate routes should have pedestrian and Americans with Disabilities Act (ADA) facilities that are equivalent to those on the existing mainline. Pedestrians may still be able to use the mainline pedestrian facilities.
- **Surfacing.** The design team should consider if improvements to the surfacing are necessary. If the detour route will need surfacing treatment before placing traffic on it, provide a sequence to ensure that it happens at the appropriate time in the contract. Local authorities should be consulted if the detour route is on local routes not administered by MDT. A construction agreement with local road authorities may be needed to address detours on local roads and streets.

10.3.9.2 Lane Closures

If sufficient room is available to maintain traffic on a portion of the existing roadway, lane closures generally are the most cost effective method of detouring traffic. Considerations include:

- **Positive Separation**. Positive separation may be needed for utility installation because trenches for storm drain and sanitary sewer can present risks. *MDT Standard Specifications for Road and Bridge Construction* includes guidance regarding traffic control at drop-off areas.
- **Access to adjacent businesses and residences**. It may be necessary to use lane closures in conjunction with detouring traffic to existing routes.
- **ADA access**. Reasonable access should be provided to both sides of the roadway, where practicable.

- **Time restrictions.** Sometimes lane closures are not allowed during peak periods. The design team should coordinate with the Traffic and Safety Bureau and/or District Traffic Engineers to determine if there are time restrictions for lane closures and develop TCPs based on construction methodologies for shorter construction timeframes.

10.3.10 Drainage Options

Where a detour would be required for a culvert replacement, the design team should consider the following options:

- **Jacking and Boring**. Jacking and boring a new pipe through the roadway fill may be cheaper than detouring traffic and excavating the fill to remove the existing pipe and install a new one. Since jacking a pipe is costly, it is usually only practical when pipes are located in higher fills or when a detour would be very expensive. The design team should compare the cost to the cost of a detour and new installation. Items to consider are:
    a. Size of pipe needed. Boring anything larger than a 48-inch culvert may be impractical and result in undue expense, since equipment to bore larger culverts is not readily available. The design team should verify the practical size for boring culverts as it may change over time.
    b. Constructability. A relatively level area at the bottom of the fill should be available to set up the jacking rig.
- **Pipe Inserts/Liners.** The Hydraulics Section should evaluate existing culverts to determine if an insert or liner can be installed rather than replacing the existing culvert. The feasibility of using a liner or insert will depend on the required culvert capacity and distortion in the existing culvert shape.

10.4 GEOMETRIC DESIGN

The design criteria presented in the following sections apply to temporary crossovers on divided highways, existing roadways through construction zones and detours specifically constructed for construction projects. It does not apply to detours along existing routes. While temporary facilities do not require formal design exceptions, when controlling criteria are not met, the design team should still consider the criteria and clearly document the design decisions in the appropriate plans and reports (see Section 10.2.3).

10.4.1 Design Speed

In addition to the geometric and physical considerations, the design of detours must take into account the expectations of the driver. Significant speed reductions through construction zones are undesirable and may lead to undesirable operating conditions particularly where normal traffic speeds are high. Regulatory or warning speed signs are generally ineffective with the exception, perhaps, of signs at horizontal curves. Temporary facilities should be designed with as high of a design speed as practical, considering the functional classification, traffic volumes, vehicle size and type, detour length, the number of travel lanes affected, duration, and project context. The design team should document and communicate to the construction personnel the limitations of the design, so that the detour can be managed and signed appropriately. If the limitations of the design are great enough that driver expectancy may be violated, the use of mitigation measures with sufficient deceleration distance in advance of the detour should be included to ensure safe operation. The use of mitigation measures may also be appropriate within longer detours with varying design speeds. The following factors should also be considered in the determination of a detour design speed:

- **Location**. If the detour is in the middle of a larger construction project, a lower design speed may be acceptable. The driver tends to be driving slower, or is at least more aware, because of the other construction activity that occurs prior to the detour. If a detour is part of a stand-alone bridge replacement project, the detour may be the first feature a driver encounters, and as a consequence may be approaching it at a much higher speed.
- **Duration**. The design speed should be as high as possible, particularly if the detour is going to be in place longer than three months.
- **Sight distance.** If the driver has plenty of advance warning that they are approaching a detour, a lower design speed may not violate driver expectancy. The design team must determine if the same amount of warning is provided at night.
- **Systems.** The design team needs to consider how this temporary construction condition along a specified road segment fits within the overall transportation system and/or corridor. The objective is to avoid unexpected change from a driver's expectation and the appropriate systematic messaging in the TCP should be established. Driver expectation for the Interstate system is particularly high, and design speeds for temporary facilities on the Interstate should be set accordingly.

The minimum acceptable detour design speed is 35 miles per hour for two-lane rural roadways, and 45 miles per hour when multiple lanes of directional traffic are detoured. However, if the design speed of the detour is more than 10 miles per hour less than the design speed of the mainline, the reasons for its use should be documented in the SOW Report. This also applies to the design speed of ramp detours as compared to the mainline. Detour design speeds for ramps and turning roadways should be established on the basis of a reasonable expectation that traffic will comply with a reduced construction speed zone. If physical constraints prohibit designing to the minimum speed, the circumstances should be documented in the SOW Report along with mitigating measures incorporated to ensure the safe operation of the detour.

10.4.2 Lane/Shoulder Widths

Desirably, there will be no reduction in the cross section width through the construction zone. However, this is rarely practical. For Interstates and other divided highways, at a minimum, an 11-foot lane width should be maintained through the construction zone and, preferably, with a 2-foot or wider right and left shoulder. Under restricted conditions, a 10-foot wide lane may be used if there is an alternative route provided for wide vehicles. Crossovers on divided highways must provide a 12-foot minimum lane width. For other highways, the lane and shoulder width selection should be 11 feet or wider. The design team should minimize the use of width reductions. Where necessary, Exhibit 10-2 presents the minimum taper rates that should be used when reducing widths.

Exhibit 10-2
Taper Rates for Lane Reductions

Design Speed (mph)	Taper Rate
20	10:1
25	15:1
30	20:1
35	25:1
40	30:1
45	45:1
50	50:1
55	55:1
60	60:1
70	70:1
75	75:1
80	80:1

Source: MUTCD (*2*).

10.4.3 Lane Closures/Other Transitions

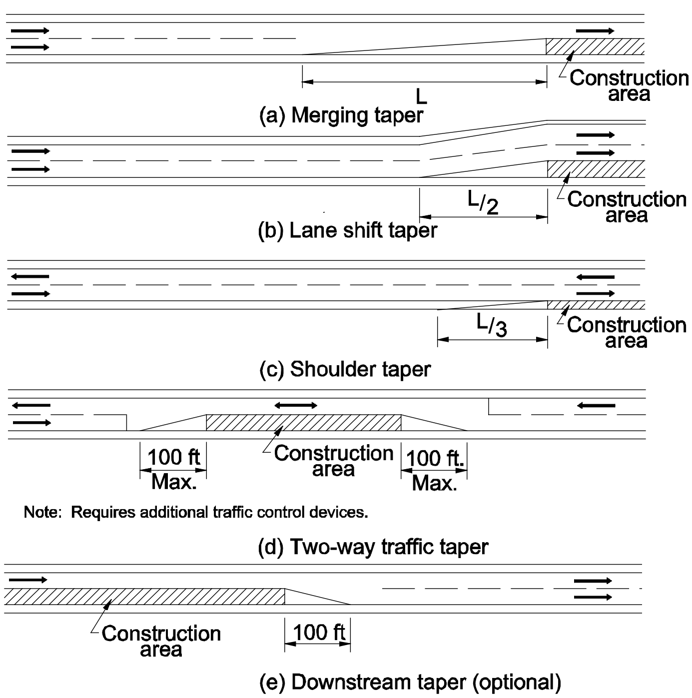
The design team should ensure that the taper rate conforms to the taper rates shown in Exhibit 10-2. Exhibit 10-3 and Exhibit 10-4 present and illustrate, respectively, the minimum taper lengths for various taper applications in construction zones (e.g., lane closures, lane shifts).

Exhibit 10-3
Taper Length Criteria for Construction Zones

TYPE OF TAPER	TAPER LENGTH
UPSTREAM TAPERS	
Merging Taper	L
Shifting Taper	1/2 L
Shoulder Taper	1/3 L
Two-way Traffic Taper	100 feet
DOWNSTREAM TAPERS (Optional)	100 feet per lane

Notes:
Length "L" determined from Exhibit 10-2.
Exhibit 10-4 illustrates the various taper types.

Exhibit 10-4
Taper Length Criteria for Construction Zones (Application)



Note: Length "L" determined from Exhibit 10-2.

10.4.4 Median Crossovers

Median crossovers built in connection with roadway construction projects on the National Highway System and Interstate Routes and left in place can be cost effective for use in construction, maintenance, and incident management.

The determination to construct median crossovers for work zone traffic control, and whether or not the crossovers will remain in place, should be discussed at the PFR. The final decision to leave the crossovers in place as a permanent installation should be made by the design team at the Plan-In-Hand and documented in the report.

Barriers and other appurtenances necessary to close the crossovers shall be installed as part of the construction project, if the median crossovers are not removed.

10.4.4.1 Plans

All details necessary to construct the median crossovers will be provided in the plans and described in the *MDT Standard Specifications* and special provisions.

10.4.4.2 Location

Crossovers should be located on horizontal and vertical tangents. Where this is impractical, crossovers should be located where adequate stopping sight distance is provided for at least the design speed of the work zone and preferably for the regular mainline posted speed of the route.

Crossovers should be located in suitable terrain, where there is minimal elevation difference between the opposing lanes. The elevation difference between the edges of median shoulders of the opposing lanes should be limited to 3 feet; however, larger elevation differences may be used where necessary depending on the median width or through modifications to a typical crossover.

The crossovers should be selected so as to not interfere with maintenance turnarounds. If this cannot be accomplished, the crossovers can be modified to function as a maintenance turnaround.

Permanent crossovers generally should not be located in close proximity to urban areas and/or interchanges.

10.4.4.3 Taper Rate

A taper rate of 12:1 should be used for the crossover, because it is comparable to what is used for exit ramps. The crossover is similar because the driver is leaving the four-lane facility and entering a two-lane facility. The same taper rate should be used for a ramp crossover. Sites will be evaluated on a case-by-case basis if constraints make the use of this taper rate impractical.

10.4.4.4 Surfacing

Unless a separate recommendation is provided by the Pavement Analysis Section, the surfacing for median crossovers will consist of 0.40 feet of plant mix and 1.0 foot of crushed aggregate course. For crossovers left in place, the design team will determine if a seal and cover or fog seal is appropriate.

10.4.4.5 Drainage

The drainage features should be designed for the same frequency storm event used for the mainline (for example, the 50-year storm event). The design team will need to ensure that adequate cover is provided over the culverts. Road Approach Culvert End Treatment Section (RACETS) should be provided on all culvert ends located within the highway clear zone.

Where practical, the crossovers should be located adjacent to median drop inlets so that no other drainage facilities are needed. The crossover should typically be sloped with an inverse crown to prevent an increase in runoff across the mainline travel lanes.

10.4.4.6 Safety Considerations

Transverse slopes for temporary median crossovers should be a minimum of 10:1. Crossovers to remain permanent should be a minimum of 20:1.

The design team should evaluate the installation of crossovers on sections where two-way traffic will have to utilize bridges that only provide a 28-foot roadway width. Due to this narrow width, the increased risk could become an issue.

It is recommended that two-way traffic on one roadway of a divided highway extend for a maximum of four miles. The length between permanent crossovers needs to be evaluated on subsequent projects and in coordination with the Traffic and Safety Bureau to determine if increased traffic volumes will result in traffic queues or congestion.

10.4.4.7 Construction

The contractor will construct and maintain the crossovers in accordance with the plans and specifications, including all necessary temporary traffic control devices.

Closure

The contractor will install pre-stretched, high tension cable rail to close the crossover upon completion of construction. If a seal and cover is not placed on the crossover, the pavement markings must be removed prior to the completion of construction.

Post-Construction Maintenance

MDT Maintenance will provide normal maintenance for the crossovers. In addition, they will inspect the crossovers to ensure that delineation and other appurtenances necessary to prevent the use of the crossover are in place and in good condition. They will repair or replace signing, delineation, and guardrail, as necessary.

10.4.5 Sight Distance

Changes in the geometric design of the existing highway are often necessary through construction zones (e.g., lane shifts, detours). Therefore, the available sight distance for the approaching motorist is important. Unfortunately, the locations of many design features are often dictated by construction operations. However, some elements may have an optional location. For example, when lane closures and other transitions are specially designed, these should be located so that the approaching driver has at least the minimum stopping sight distance available to the closure or transition. Providing Decision Sight Distance is preferred. The minimum stopping sight distances are presented in Chapter 2, Section 2.8, and the *Baseline Criteria Practitioner's Guide*, and will be based on the construction zone design speed.

10.4.6 Horizontal Curvature

10.4.6.1 Minimum Radii/Superelevation

The minimum radii and superelevation of any horizontal curves will be determined using the selected design speed for the construction zone (Section 10.4.1) and based on the principles outline in Chapter 3. In construction zones, the AASHTO Method 2 for distributing superelevation and side friction may be used to determine the radius and superelevation rate of any curve. In this method, superelevation is introduced only after the maximum allowable side friction has been used. This results in eliminating superelevation on flatter curves and reducing the rate of superelevation on the majority of other curves.

The PTW width is considered the full finished top width of the existing facility, and is not just the through lanes as defined for "traveled way".

Typically, the present traveled way (PTW) is widened for the detour connection using the same cross slope as exists on the PTW. Exhibit 10-5 provides the minimum horizontal curve radii for retaining normal crown, based on AASHTO Method 2, for detour connections to tangent PTW sections. Detour connections to superelevated PTW sections should be accomplished with horizontal curves requiring the same superelevation, based on AASHTO Method 2, as the in-place superelevation of the PTW. As discussed in Chapter 3, Section 3.3.7, the minimum distance between the PT and PC of reverse superelevated curves will be that needed to meet the superelevation runoff length requirements for each of the two curves.

Exhibit 10-6 illustrates a typical three-horizontal curve alignment for a minimum-length, 50-miles-per-hour, constructed detour providing approximately a 50-foot offset. The following factors should be considered when establishing a detour alignment:

- Selecting radii requiring a normal crown (NC) for curves exiting/entering tangent PTW accommodates vehicles turning onto/off the detour on the retained adverse crown of the PTW.
- Selecting radii requiring NC allows the PC and PT of successive curves to be coincident and eliminates the need for superelevation transition lengths.
- If selection of radii requiring superelevation is necessary, ensure that the proper transition lengths are provided as shown in Exhibit 10-7.
- Typical offsets between the edge of a new structure and the edge of a detour shoulder is 10 feet.
- Provide a 2-foot radius nose at the gore.

Exhibit 10-5
Minimum Radii for Horizontal Curves (Construction Zones)

Design Speed, V (mph)	f_{max} (Open-Roadway Conditions)	Min Radii, R_{min} (for Normal Section) (e = -2%) (ft)	Min Radii, R_{min} (e = 8%) (ft)
20	0.27	110	80
25	0.23	200	140
30	0.20	340	220
35	0.18	520	320
40	0.16	770	450
45	0.15	1040	590
50	0.14	1390	760
55	0.13	1840	960
60	0.12	2400	1200
65	0.11	3130	1480
70	0.10	4090	1810

Notes:

1. **Curve Radii**. Radii are calculated from the following equations:

   $R = \frac{V^2}{15(e+f)}$ values for design have been rounded up to the next highest 10-foot increment.

2. **Normal Section**. If the normal section is maintained through the horizontal curve, the superelevation rate is -0.02 assuming a typical cross slope of 2%. Therefore, the R_{min} column with e = -2% presents the minimum radii which can be used and retain the normal section through the horizontal curve.
3. **Other Radii.** For proposed radii or superelevation rates intermediate between the table values, the equation in Note #1 (Curve Radii) may be used to determine the proper curvature layout. For example, if the construction zone design speed is 60 mph and the proposed curve radius is 1,640 feet, then the superelevation rate is:

$$e = \frac{V^2}{15R} - f$$

$$e = \frac{(60)^2}{(15)(1640)} - 0.12$$

$e = +2.6\%$, round to +3.0%

(Round the calculated superelevation rate to the next highest percent).

Exhibit 10-6
Typical Detour Alignment (Maintaining Normal Crown Section) (Design Speed: 50 mph)

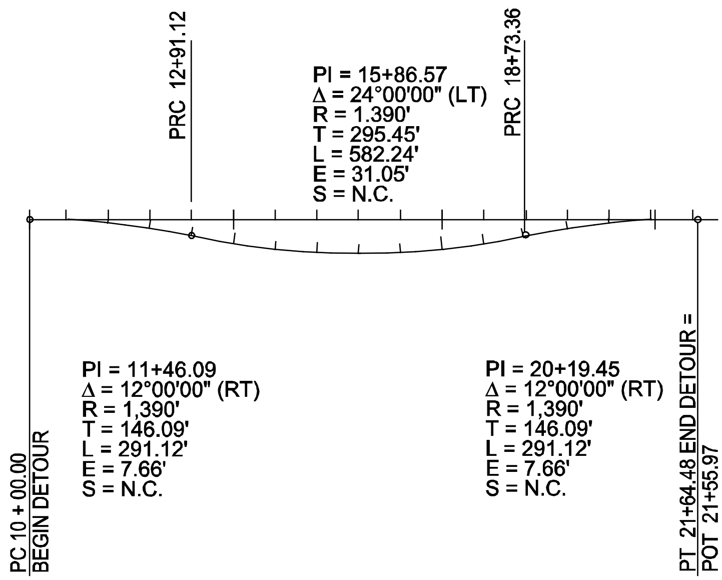
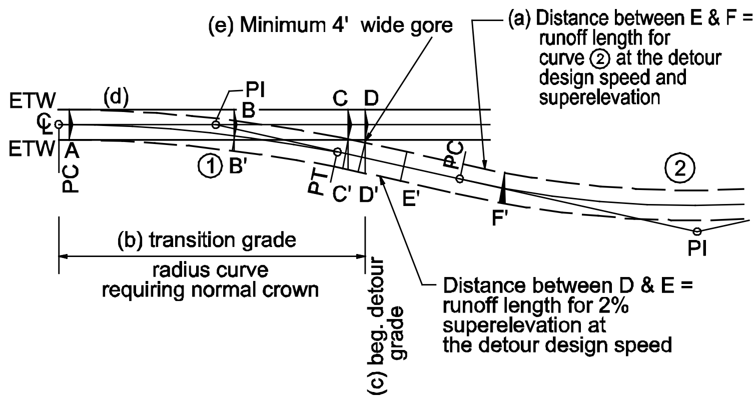
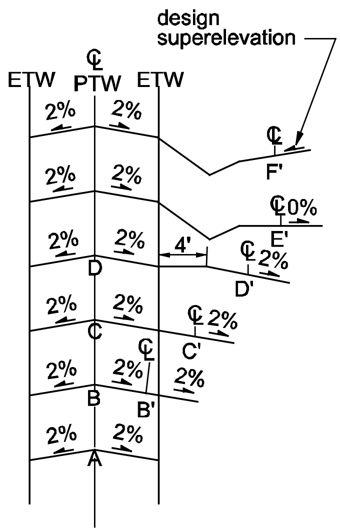


Exhibit 10-7 Horizontal Curves for Detours (With Superelevation)





(a) This applies if Curve 2 is superelevated. If Curve 2 is flat enough to retain the normal crown, the PT of Curve 1 and PC of Curve 2 can be coincident. Transitioning the 2% cross slope at Section D' to normal crown can then be accomplished within Curve 2.

(b) Throughout the transition grade, detour centerline elevations are computed by multiplying the offset distance and the cross slope between the centerlines. This distance is then subtracted from the mainline centerline elevation.

(c) Independent detour grade begins at the point of full separation between mainline and detour (Section D').

(d) Detour connections to a curved present traveled way (PTW) alignment should be accomplished with a horizontal curve requiring the same superelevation, based on Exhibit 10-6, as the in-place superelevation of the PTW.

(e) This distance is typically added to the shoulder widths of the mainline and detour (if they have them) and not measured between edges of the traveled way as shown. The gore nose typically matches the cross slope of the mainline or provides a shallow ditch profile for drainage.

10.4.6.2 Transition Lengths

Chapter 3, Section 3.3.4 presents MDT criteria for superelevation transition lengths for permanent construction projects. These lengths will be provided for detours in construction zones and are based on detour design speed. Note that superelevation is transitioned throughout the detour using a continuously rotating plane in Exhibit 10-7.

Chapter 3 provides information for determining transition length for two-lane, two-way roadways in rural conditions, multilane roadways in rural conditions, and roadways in urban conditions.

10.4.7 Vertical Alignment

A transition grade should be used for the detour alignment from the beginning/end of the detour to the gore. An independent grade should be designed between the gores.

Throughout the transition grade area, detour centerline elevations are computed from the PTW profile and cross slope, similar to transition grades for ramps or other turning roadways. Additional information on transition grades for detours is provided in Chapter 4, Section 4.2.6.

If a detour crosses a water feature, ensure that the detour grade provides minimum cover for all culvert options to accommodate the waterway opening or the elevation required for placement of the temporary bridge.

Vertical curve criteria presented in Chapter 4 is also applicable to detours.

10.4.8 Surfacing

All detours for Interstate projects will be paved. Detours for projects on other routes may have paved, treated or gravel surfaces. Factors that influence the type of surfacing used for these detours include:

- The Average Daily Traffic (ADT) on the route (routes with higher ADT's require more durable surfacing),
- The length of time the detour will be in use,
- The anticipated detour posted speed, and
- The maintenance that would be required for the various types of surfacing. The ADT will also affect the level of maintenance.

See Exhibit 10-8 for general guidance as to the type of surfacing for detours.

Exhibit 10-8
Guidelines for Selection of Detour Surfacing

Current ADT	Duration of Detour Operation			
	< 5 Days	5 - 30 Days	31 Days - 3 Months	> 3 Months
< 500	Gravel	Gravel	Treated Gravel	Treated Gravel
500 - 1499	Gravel	Treated Gravel	Treated Gravel	Plant Mix Surfacing (PMS)
1500 - 6000	Treated Gravel	Treated Gravel	PMS	PMS
> 6000	Treated Gravel	PMS	PMS	PMS

Notes:
Gravel is untreated crushed aggregate course (CAC).
Treated gravel is CAC that has an aggregate treatment applied to the riding surface to help control dust and add durability.
Plant Mix Surfacing (PMS) is a paved surface on top of a CAC base.

10.4.9 Cut and Fill Slopes

Wherever practical, construct detour cut and fill slopes according to the *MDT Baseline Criteria Practitioner's Guide* and Chapter 9 *(3)*. The use of 3:1 fill slopes is acceptable where a sufficient clear zone is available at the bottom of the slope. The use of steeper fill slopes may require the installation of barriers.

Although detours rarely involve excavation (cut), 3:1 cut slopes are generally acceptable in place of the 5:1 and 4:1 slopes described in the *Baseline Criteria Practitioner's Guide* and Chapter 9 (*3*). The use of slopes steeper than 3:1 for cut depths less than 10 feet should be reviewed at the Plan-in-Hand.

The anticipated traffic volumes, design speed of the detour and the length of time the detour will be in place should be weighed in determining cut and fill slopes.

10.4.10 Temporary Pavement Markings

Temporary pavement markings provide guidance for roadway users traveling through the construction area. Additionally, temporary pavement markings may be required:

- After milling operations (if traffic will be driving on the milled surface), and
- Between each pavement lift.

They may also be required on existing pavement, which may require the removal of permanent pavement markings to eliminate conflicting messaging. Chapter 13 presents the procedures for estimating quantities.

10.5 ROADSIDE SAFETY

As drivers traverse construction zones, they are often exposed to numerous challenges including restrictive geometrics, construction equipment and opposing traffic. Elimination of these restrictions is often impractical. Regardless, consideration must be given to reducing the exposure of motorists to risks.

10.5.1 Positive Protection

During the planning and design of a project, give careful consideration to traffic control plan alternatives that do not require the use of temporary barriers. This can often be accomplished by using detours, constructing temporary roadways, minimizing exposure time, and maximizing the separation between traffic and workers. Even with proper project planning and design, there will still be instances where positive protection should be considered.

Because each site should be designed individually, MDT has no specific warrants for providing positive protection in construction zones. The design team should coordinate with the Construction Bureau and field construction personnel to make the determination whether to provide positive protection in construction zones and capture the decision in the TCP. The *MDT Standard Specifications for Road and Bridge Construction* can be used as a reference to assist in the decision process. The following provides a list of factors that should be considered:

- Duration of construction activity,
- Clear zone for the construction zone design speed,
- Traffic volumes (including seasonal fluctuations),
- Nature of potential conflict,
- Design speed,
- Highway functional class,
- Length of hazard,
- Proximity between traffic and construction workers – consider dynamic deflection of barrier,
- Proximity between traffic and construction equipment,
- Adverse geometrics which may increase the likelihood of run-off-the-road vehicles,
- Two-way traffic on one roadway of a divided highway, and
- Transition areas at crossovers, and/or lane closures or lane transitions.

10.5.2 Appurtenance Types

The first objective should be to provide a design that eliminates the need for temporary barriers. However, this is often not practical. In addition to Chapter 9 and the *MDT Detailed Drawings*, the following provides general information on the roadside safety appurtenances used by MDT through construction zones:

- **Guardrail/Barrier Rail.** For most construction projects, the installation of a new temporary guardrail/barrier rail is usually not cost effective due to the short project life. Where used, temporary guardrail/barrier rail installations must meet the permanent installation criteria set forth in Chapter 9 and the MDT Detailed Drawings, except where modified in Section 10.5.3.
- **Temporary Concrete Barrier Rail (TCBR)**. The most common type of portable barrier is a TCBR. A TCBR provides the greatest protection from the construction zone and between two-way traffic, but it is also the least forgiving to the driver. The primary functions of the TCBR in construction zones are:
    a. To keep traffic from entering work areas (e.g., excavations, material storage sites);
    b. To protect workers and pedestrians;
    c. To separate two-way traffic;
    d. To shield obstacles and edges; and
    e. To protect construction such as falsework for bridges and other exposed objects.

  To determine the appropriate temporary barrier placement, the site should be classified as high or lower risk. A high risk situation is

The design team should consider the horizontal clearance if TCBRs are installed along both sides of the temporary roadway to accommodate oversized/overweight heavy vehicles.

defined as a situation in which a barrier placement that exceeds the design deflection will likely result in death or injury. (An example would be a vertical drop off along the edge of Phase 1 on a phased bridge construction project.)

High Risk Sites

For high risk sites, anchor (pin down) the temporary barrier as shown in the Detailed Drawings.

Lower Risk Sites

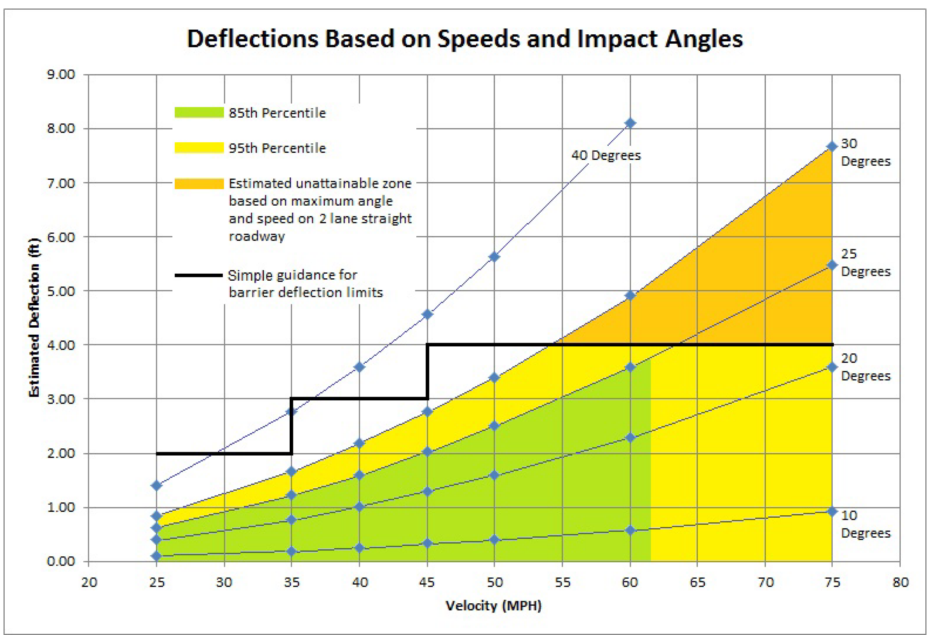
For lower risk sites with straight roadways and with a single lane or two lanes in the same direction, a simple approach is to pin down the barrier, if there is not sufficient space to accommodate the minimum deflection limit. The minimum deflection limit is shown in Exhibit 10-9.

Exhibit 10-9 Minimum Deflection Limits

Speed (mph)	Deflection (ft)
Less than 35 mph	2
35 - 44 mph	3
45 mph or greater	4

The minimum deflection limit shown in Exhibit 10-9 is conservative for many applications. Exhibit 10-10 provides a more refined estimate of deflection for curved roadways, or for three-lane or larger roadways. The speed and impact angle can be used to determine deflection, or alternatively, available deflection and impact angle can be used to determine the appropriate speed limit.

Exhibit 10-10 Deflections Based on Speeds and Impact Angles



Source: MDT, 2015 (4).

Each site will require consideration of all factors to develop a site-specific deflection limit. The list of factors that should be considered and used to adjust the indicated deflection limit as appropriate is in Section 10.5.1.

The decision on where to use a TCBR in construction zones will be determined on a site-by-site basis. The design team needs to coordinate with District Construction to determine the extent of the TCBR and how many times it will be reset.

- **End Treatments.** Even when protected or otherwise mitigated, the ends are the most hazardous element of any barrier system. Therefore, any unprotected terminal ends for guardrail or the TCBR should be located as far as practical from the roadway (outside the clear zone) or be protected with an appropriate end treatment.

The end treatment to protect the blunt end of the CBR should be selected to best fit the project context and should be properly documented in the appropriate plans and reports (see Section 10.2.3).

Chapter 9 provides information on other end treatments used by MDT. Provide the safest end treatment consistent with cost effectiveness and geometric considerations.

10.5.3 Design/Layout

In general, when designing and laying out temporary roadside safety appurtenances in construction zones, use the criteria set forth in Chapter 9. However, due to the limited time exposure, it may not always be cost effective to meet the permanent installation criteria. The following provides several alternatives the design team may use in designing and laying out temporary roadside safety appurtenances:

- **Clear Zones.** Applying the clear zone distances for new construction/reconstruction, as presented in Chapter 9, to construction zones is often impractical. MDT has developed revised distances for clear zones through construction zones, which are presented in Exhibit 10-11. Due to the hazardous conditions which typically exist in construction zones, the design team still should use considerable judgment when applying these clear zone distances. Note that it is not necessary to adjust the construction clear zones in Exhibit 10-11 for horizontal curvature.
- **Length of Need.** As with new installations, provide a sufficient distance of a full-strength barrier prior to the hazard to minimize the potential for a vehicle to run behind the barrier and impact the hazard. For temporary layouts, determine the length of need by using an angle of 15 degrees from the back of the hazard or from the clear zone distance off of the edge of traveled way.
- **Shoulder Widening.** When a temporary barrier is placed next to the shoulder, it is not necessary to provide the extra 2 feet of shoulder widening.

- **Flare Rates.** Desirably, the CBR terminus should be flared away from the traveled way to a point outside of the clear zone. Exhibit 10-12 presents the desirable flare rates for the CBR based on the design speed in construction zones. The design team should provide these flare rates unless under extenuating circumstances it is impractical to do so (e.g., stop conditions, driveways, intersections).
- **Departure Angle.** As discussed in Chapter 9, based on a number of field studies, the 80th percentile angle of departure is estimated to be 15 degrees. These flat angles of departure result in the need to extend the barrier a distance in front of the obstacle, which determine the length of need. More information is provided in Chapter 9.

**Exhibit 10-11
Clear Zone Distances (ft) (Construction Zones)**

All distances are measured from the edge of the traveled way (ETW).

For clear zones, the ADT will be the total current ADT for both two-way roadways and one-way roadways.

Detour Design Speed	ADT	Fill Slopes 6:1 or Flatter	5:1	4:1	3:1
35 mph or less	< 750	3	5	5	See Procedure in Section 9.2.2.
	750-1499	5	6	8	
	1500-6000	6	7	8	
	> 6000	8	8	10	
45 mph	< 750	5	6	7	
	750-1499	6	8	10	
	1500-6000	8	10	12	
	> 6000	10	12	13	
50 mph	< 750	6	6	8	
	750-1499	8	10	10	
	1500-6000	10	12	13	
	> 6000	12	13	15	
55 mph	< 750	6	8	10	
	750-1499	8	10	12	
	1500-6000	10	13	15	
	> 6000	11	13	16	
60 mph	< 750	8	10	12	
	750-1499	10	13	16	
	1500-6000	13	16	20	
	> 6000	15	18	23	
70 mph	< 750	10	12	14	
	750-1499	12	15	18	
	1500-6000	15	18	21	
	> 6000	16	20	23	

Notes:
See Section 9.2.2.3 for application of clear zones in cut sections.

Exhibit 10-12
Flare Rates for Temporary Concrete Barrier Rail

Detour Design Speed	Flare Rates
45 mph or less	9:1
50 mph	11:1
55 mph or greater	13:1

10.6 DRAINAGE STRUCTURES

The Hydraulics Section will determine the type of temporary drainage structures that are required for detours or crossovers. If a bridge will be needed, the Hydraulics Section will provide the dimensions for the waterway opening.

10.6.1 Perennial (Active) Streams

The design team should coordinate with the District Biologist early in the detour design process to determine the treatment that should be used in conjunction with the culvert installation and to address other environmental challenges associated with the detour. Prior to installing the detour culvert in a perennial stream or a stream with a high resource value, one of the following treatments will be required.

- Place drain aggregate in the channel bottom extending 2 feet beyond each side of the active channel. The drain aggregate should be placed to an average depth of 6 inches for the entire length of the culvert. (drain aggregate is defined in the *Standard Specifications*). This treatment is typically preferred for use in perennial streams. Or,
- Place erosion control geotextile in the active channel. The geotextile should extend 2 feet beyond each side of the active channel for the entire length of the culvert.

Geotextile must also be placed on the upstream and downstream face of the detour embankment. The geotextile should be keyed into the toe of the fill and the top of the fill. It should extend at least 3 feet beyond the defined channel banks. Note that the defined channel banks may not be the same as the active channel.

10.6.2 Intermittent & Ephemeral Streams

The following treatment should be used for intermittent or ephemeral streams.

- Place drain aggregate or hay/straw in the channel bottom extending 2 feet beyond each side of the low water channel. The drain aggregate, hay, or straw should be placed to an average depth of 6 inches for the entire length of the culvert (drain aggregate will meet the requirements in the *Standard Specifications*).
- If wetlands or riparian areas are impacted by the detour embankment outside of the banks of any stream, geotextile, drain aggregate or hay or straw should still be placed over the affected wetlands or riparian

areas to delineate the original ground elevation (i.e., the treatment will be placed the entire width and length of the base of detour embankment through wetland/riparian areas).

10.7 REFERENCES

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